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SURFACING LOSS STUDY

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SURFACING LOSS STUDY

Purpose

The purpose of this study is to determine the parameters that are associated with surfacing loss on untreated aggregate surfaced Forest roads located in the south-central portion of Oregon. A statistical method is used to evaluate the influence of each parameter. From this evaluation a relationship is developed to estimate loss in order to program surface aggregate replacement.

Method of Study

Twenty-three field stations were established on eight aggregate-surfaced roads during the summer of 1970. These roads were located on the Fremont, Rogue River and Winema National Forests and included surfacing material of cinders and basalt aggregate. The road test stations were established to include a variety of width, curvature, grade and cross section.

At each station four transverse cross sections were established 25 feet apart. Bench marks were set and the road cross sectioned at 1-foot intervals along each of the transverse lines from shoulder to shoulder. Settlement plates were installed on top of the subgrade at each section to measure any settlement in the subgrade.

Field samples of the surfacing material were obtained at each station and a variety of engineering tests were performed on the aggregate by the Regional Materials Laboratory.

Finally, automatic traffic counters were placed in the vicinity of each station to measure the traffic using the road. Total timber haul on each road was also measured and the traffic distribution between timber haul and other types of traffic calculated.

A more detailed explanation of the initial study is presented in Mr. J. Crabtree's "Proposal for Surface Loss Measurements on Soil-Aggregate Roads" dated August 28, 1970. This report is included in the appendix.

Data Collection

Initially, traffic and weather data were to be collected monthly and the surface recross sectioned approximately every three months. Due to breakdown of some of the counters, lack of some data collection and transfer of key supervisory personnel, this goal was not accomplished satisfactorily. During the spring of 1972 a preliminary analysis was made of the available data. In many cases data from recross sections were taken in the winter which indicated an expansion of the road surface, probably resulting from frost heave. Due to this problem and lack of other key data, only eight of the 23 stations could be analyzed. Based on a linear multiple regression analysis some trends were observed, but it was felt that the data and number of examples were insufficient to justify any specific conclusions.

A final recross section of each station was then undertaken during the summer of 1972 under the supervision of the author. In addition, each Forest was contacted to obtain their best estimate of traffic and maintenance data over the particular section during the past two years. The surfacing loss could then be computed for the two-year period, thus eliminating the problem of winter frost heave and the effect of different time periods for each station.

This final measurement was undertaken to obtain reliable data for each section and hopefully to salvage all the work that had been put into the original study.

No weather or dusting data were collected at this time. This information is difficult to measure and evaluate, and a trend of low correlation with loss was indicated in the preliminary analysis.

All of the original 23 stations were located and cross sectioned. Of these, 16 were felt satisfactory for analysis. The remaining seven were eliminated due to errors in establishing the original section (1), loss of control points or questionable bench marks as indicated by expansion in the surfacing (2), and the addition of new surfacing material (3). One road (#3017 on the Rogue River National Forest) had a penetration treatment applied to it a month before the final cross section. Since no new surfacing aggregate had been added and only the voids in the aggregate were filled with asphalt, it was felt justifiable to include these stations. The loss that might have occurred during that last month was not felt to be significant.

Traffic and maintenance data were obtained with reasonable accuracy for all of the test roads. Materials test data were based on the original samples taken in 1970 and geometric alignment data were based on the original observations.

The surfacing loss for the entire two years was calculated for four different situations:

1. Loss in cubic yards for the entire 75 foot station, uncorrected for settlement (designated as TLU in the equations).

2. Loss in cubic yards for the entire 75 foot station, corrected for settlement based on the settlement plate (designated as TLC in the equations).

3. Loss in cubic feet for one square foot of road surface, uncorrected for settlement (designated as LU in the equations).

4. Loss in cubic feet for one square foot of road surface, corrected for settlement based on the settlement plate (designated as LC in the equations).

Both the uncorrected and corrected settlement readings were investigated as it was difficult to determine if the settlement was localized under the 4 in. x 4 in. x 1/8 in. plate or if it was typical of the entire station. The settlements varied between zero and 0.08 foot with 0.01 foot being the average.

The values for loss determined under items 3 and 4 above are also the average loss in thickness for each of the stations measured in feet and are independent of the width.

Results

The data for 16 stations and 32 variables (4 dependent and 28 independent) were analyzed by a linear multiple regression program (BMD 02R - Stepwise Regression as developed by the Health Sciences Computing Facility, UCLA).

Each of the 4 loss values listed in the previous section were individually used as the dependent variable with the remaining 28 variables evaluated as to the best estimator for loss. A list of the variables along with their mean, standard deviation and correlation with loss are listed in the appendix. The best fit equations and correlations for one variable and six variables in the order of importance for each loss situation are as follows:

TLU_1 = 2.852 + 0.08161 (MMBF)
CC = 0.5642

TLU_6 = 68.724 + 0.1023 (MMBF) + 1.406 (F/C) - 0.9402 (SSF) - 0.4345 (P 3/4) - 0.2352 (SNOW) - 0.1572 (D MAX)
MCC = 0.9160

TLC_1 = 1.633 + 0.09018 (MMBF)
CC = 0.7570

TLC_6 = 18.349 + 0.1162 (MMBF) + 3.533 (F/C) - 0.6214 (SSF) - 0.1273 (SNOW) - 0.2085 (P 3/4) + 0.8559 (O-H)
MCC = 0.9180

LU_1 = 0.04893 + 0.00077 (MMBF)
CC = 0.4684

LU_6 = 0.2525 + 0.00711 (LAA) + 0.03057 (GRADE) - 0.01108 (P 200) - 0.00092 (MMBF) - 0.00284 (P 40) - 0.00183 (SSC)
MCC = 0.9108

LC_1 = 0.03316 + 0.00088 (MMBF)
CC = 0.7045

LC_6 = 0.3253 + 0.00154 (MMBF) + 0.03181 (F/C) + 0.00032 (CURVE) - 0.00341 (P 3/4) - 0.00075 (TTU) - 0.00331 (SSF)
MCC = 0.9204

where,

TLU, TLC, LU and LC = loss as described on page 3

CC = correlation coefficient (simple)

MCC = multiple correlation coefficient

(See page 2 of the appendix for a definition of the remaining variables.)

As can be seen from these equations, timber haul (MMBF) was the most significant variable, explaining from 22 to 58 percent of the variation in loss, with maintenance; roadway geometrics; and surfacing material properties helping to explain most of the remainder of the variation.

The independent variable for timber hauled (MMBF) was the actual volume hauled allowing for "off-highway-loads." Only one road had "off-highway-loads," road 348 on the Fremont National Forest. This road also had the highest total volume of timber, 131 MMBF, and thus had a strong influence on the correlation with loss and the resulting equation. Since very few intermediate timber volumes existed, the data were also analyzed without road 348. Corrected loss per square foot (LC) is used as an illustration. The results of a sum of least squares fit are shown in figure 1 and graphically demonstrate this strong influence of the two data points from road 348.

Since there appeared to be a large difference in results between these two methods (1 inch of loss for 95 MMBF vs 55 MMBF) the data were re-examined in another form. These revised data considered each load of logs as one truck regardless of volume carried. The revised data points using trucks instead of MMBF have the same relative location except for those from road 348 which are moved in closer to the origin. As can be seen from figure 2, the best fit curves for those considering all points and those not considering road 348 are fairly close together (1 inch of loss per 11,000 trucks vs 9,200 trucks) and the best fit curve through the origin in 1 inch of loss per 7,400 trucks. At 5,000 BF per truck load these results would correspond to 1 inch of loss per 55, 46 and 37 MMBF respectively.

Since the above results had a maximum correlation coefficient of 0.715, or with only 51 percent of the variation in loss being explained by timber haul, further analysis was necessary. Multiple regression equations were then developed using a maximum of six independent variables. The best fit equations and correlations for one variable and six variables in the order of importance for each loss situation are as follows:

$TLU_1 = 1.019 + 0.9274\ (LT)$
$CC = 0.6277$

$TLU_6 = 54.957 + 1.254\ (LT) + 1.363\ (FK) - 0.294\ (SNOW) - 0.845\ (SSF) - 0.402\ (P\ 3/4) - 0.103\ (D\ MAX)$
$MCC = 0.9284$

$TLC_1 = 0.151 + 0.9121\ (LT)$
$CC = 0.7495$

$TLC_6 = 19.014 + 1.676\ (LT) - 0.604\ (SSC) - 0.248\ (SNOW) - 0.222\ (P\ 3/4) + 0.100\ (SE) + 0.524\ (PI)$
$MCC = 0.9266$

$LU_1 = 0.0281 + 0.00950\ (LT)$
$CC = 0.5633$

$LU_6 = 0.469 + 0.02490\ (LT) + 0.0427\ (F/C) - 0.00196\ (TTU) - 0.00492\ (P\ 3/4) - 0.00620\ (SSF) + 0.00097\ (LL)$
$MCC = 0.9246$

LC_1 = 0.0177 + 0.00910 (LT)
CC = 0.7151

LC_6 = 0.273 + 0.01905 (LT) + 0.0296 (F/C) - 0.00117 (TTU) - 0.00256 (P 3/4) - 0.00335 (SSF) - 0.00106 (P40)
MCC = 0.9290

(The variables are defined on page 2 of the appendix.)

Again, the most significant variable was related to log haul or in this case the number of log trucks (LT)

The independent variable for traffic units was used originally as total traffic (TTU), which included logging trucks. All logging trucks were counted as ten traffic units (round trip) regardless of board feet of timber hauled, and passenger vehicles were counted as two units (one way).

Since log haul had already been accounted for, it was decided to investigate the effect of changing total traffic units (TTU) to other traffic units (OTU) that would include traffic other than log haul. The other traffic would primarily be passenger cars and pickup trucks. This correlation with loss is included in the appendix along with the other independent variables.

The net effect of this change affected only the loss per square foot equations and did not alter the order of importance of the other variable in any equation. The two new equations are as follows:

LU_6 = 0.469 + 0.00920 (LT) + 0.0427 (F/C) - 0.00196 (OTU) - 0.00492 (P 3/4) - 0.00620 (SSF) + 0.00097 (LL)
MCC = 0.9246

LC_6 = 0.273 + 0.00965 (LT) + 0.296 (F/C) - 0.00117 (OTU) - 0.00256 (P 3/4) - 0.00335 (SSF) - 0.00106 (P40)
MCC = 0.9290

As can be seen, the only change in the equations are the coefficients for the number of log trucks (LT). No advantage is obtained by considering this new equation.

Discussion

It was felt that corrected loss per square foot (LC) would be the most valid loss situation to consider in the analysis. This allowed loss to be computed independent of width and also gave a value of thickness loss directly. The question of the validity of the settlement plates could not be discounted, thus they were assumed to be reasonable.

The independent variable that had a correlation above 0.300 with loss (LC) are as follows:

Log trucks (LT)	0.715
Log haul (MMBF)	0.705
Percent grade (GRADE)	0.633
Total traffic units (TTU)	0.460
Specific gravity (SG)	-0.431
Oregon degradation height (O-H)	-0.369
Sodium sulfate fine (SSF)	-0.365
Los Angeles abrasion (LAA)	0.328
Roadway width (WIDTH)	0.325

As can be seen, the most important variables are related to traffic, roadway geometrics and material properties. The positive correlation with total traffic units (TTU), log haul (MMBF) and log trucks (LT) are obvious, indicating more loss with more traffic or use. Grade in percent and width in feet correlation indicate that loss increases as these values increase. The correlation with grade appears logical, however the correlation with width probably indicates that the wider roads are more heavily traveled and maintained to a higher standard, thus incurring more loss in thickness. The correlation of specific gravity (SG) and Los Angeles abrasion loss (LAA) appear logical, indicating that softer or more porous aggregates are subject to more breakdown, thus more loss. The correlation of Oregon degradation sediment height (O-H) and sodium sulfate soundness loss for fines (SSF) are less obvious and are probably related to the generation of plastic fines which are necessary for a good aggregate surfaced road. Material type (cinders or basalt) was weakly significant, with cinders indicated to have a slightly higher loss.

Maintenance and snow removal frequency had a weak but positive correlation with loss. This indicates that the more intensive the maintenance activity the more the loss. The one item that could not be measured quantitatively but had a strong influence on loss was the quality of maintenance and the maintenance procedure. Based on personal observations and discussion with District personnel, this item appeared to be important. What was observed to take place was that during blading the loose surface material was partially removed, ending up as surface widening on the shoulders. Thus, a 14-foot wide road would become 16-foot wide over a period of time. The surface would not be actually "lost" but just displaced. In other cases, if proper watering and compaction equipment were not available, much of the loose surfacing would be bladed over the fill slopes or into ditch bottoms. This was especially true of pit run aggregate where there was much oversized material that prevented recovery with the grader. Grades and curves compounded this problem as the material would already be displaced due to traffic.

In summary, surfacing loss is caused by traffic, primarily due to log haul traffic. Poor surfacing aggregate properties will accelerate the wear and breakdown of the material and adverse road geometry will accelerate the displacement of the material. The actual loss is due primarily to the maintenance procedure generated by the traffic and to a lesser extent by compaction of the surfacing material and mixing with the underlying subgrade. A minor amount is probably lost due to dusting and individual particles thrown off by traffic.

Conclusion

Two recommendations appear necessary; one, the best procedure to estimate surfacing loss for a particular road; the other, a rate to assign users for the estimated replacement.

The best estimate of loss is to consider loss per square foot or thickness of loss, as this is independent of width. The multiple regression equations developed in the results section are applicable; however using one independent variable (LC_1) does not give sufficient accuracy and using six independent variables (LC_6) requires the collection of too much data. Using four variables the equation for corrected loss per square foot is:

$$LC_4 = 0.162 + 0.0188\ (LT) + 0.0382\ (F/C) - 0.00110\ (TTU) - 0.00213\ (P\ 3/4)$$

This equation has a multiple correlation coefficient of 0.8882, or it explains 79 percent of the variation in loss. The equation requires only traffic data in the form of total number of loaded log trucks and total traffic units (two ways; whether the roadway prism is in fill (F/C = 1.0), cut (F/C = 2.0) or sidecast (F/C = 1.5), and the percent passing the 3/4 inch sieve which in most construction contract cases would be near 100 percent. This equation also avoids the requirement for the sodium sulfate soundness test, which requires involved testing procedures.

Assuming 100 percent passes the 3/4 inch sieve, essentially all traffic being logging, and the road equally in fill and cut, the equation would reduce to:

$$LC = 0.0063 + 0.0078\ (LT)$$
(loss in feet of thickness)
$$= 0.0756 + 0.0936\ (LT)$$
(loss in inches of thickness)

This gives approximately 1 inch of thickness loss per 10,000 loaded log trucks, or assuming 5,000 BF per loaded log truck, approximately 1 inch of thickness loss per 50 MMBF.

Surfacing materials with 100 percent passing the 3/4 inch sieve are usually from crushed material, and thus are of a higher type construction and have a dense gradation. More oversize material, indicative of a poorer gradation, would have a smaller percentage passing the 3/4 inch sieve, thus more surfacing loss per truckload.

The assignment of replacement rates to users appears to be related to timber haul. Total traffic in the form of traffic units is poorly correlated with loss but in a positive direction. However, when traffic other than logging is considered, the correlation is negative, though only slightly. Thus log haul appears to be the source (directly or indirectly) of loss, in the form of board feet hauled or as the number of truckloads. The most reliable data, as discussed earlier, appears to consider log haul in the form of loaded log trucks. Referring to figure 2, two alternatives exist: Either consider the best fit curve for all points at the rate of 1 inch of loss per 9,200 trucks or the curve through the origin at 1 inch of loss per 7,400 trucks.

An intermediate rate of 1 inch of loss per 8,000 trucks is recommended. Considering loaded trucks to generally carry 5,000 BF, this gives 40 MMBF per inch of loss. This value is a greater rate than the 50 MMBF rate developed earlier, but it is felt to represent the typical situation.

The thickness loss in all of the above discussion refers to compacted thickness in place in the roadway. Surface replacement often is measured and purchased in the stockpile or by the truckload. In either case, the material is in a loose, uncompacted state and thus the volume is greater. If the material shrinks 25 percent from stockpile to compacted roadway due primarily to densification, then the quantities calculated from the equations of this report must be increased by 33 percent. Stockpiling and handling losses may also be a consideration in selecting a "compaction" factor.

As an example, 0.100 foot of loss for a 27 foot wide roadway would require 0.100 cubic yard per running foot replacement as measured in place in the roadway. Assuming 33 percent increase from roadway to stockpile, a volume of 0.133 cubic yard per running foot should be stockpiled.

Summary

The following conclusions and recommendations appear to be valid:

1. A typical aggregate surface road under the drier climate of the east side of the Cascades will experience one inch of surfacing loss per 8,000 loaded log truck applications.

2. For a skillfully maintained road with a dense graded 3/4 inch minus aggregate the loss under the same situation is approximately 1 inch per 10,000 trucks. An equation is provided for a more precise calculation.

3. This loss appears to be independent of the volume of timber hauled per load.

4. The loss is not related to light vehicular traffic such as passenger vehicles and pickup trucks.

5. The loss appears to be slightly greater for cinder than for basalt aggregate, however the difference is not significant using the data available (refer to #7 regarding aggregate strength properties).

6. Maintenance procedure and frequency are related to loss, often in the form of a widened cross section or material lost over banks and into ditches.

7. Poor aggregate properties as determined by standard materials tests (Los Angeles abrasion, Oregon degradation, specific gravity and sodium sulfate soundness) will accelerate the loss.

8. Adverse alignment such as sharp curves and steep grades will also accelerate the loss due to displacement of material by traffic.

9. Additional data points should be obtained by carrying the surviving test sections through another year and by attempting to salvage available test data for the first year of operation.

10. Similar test sections with larger and several settlement plates per test station should be established on other Forests to determine the effects of climate, especially the wet weather of the west side Forests.

11. Future test sections should have an accurate determination of the aggregate surface width to obtain quantitative data on subsequent widening through maintenance.

12. Inplace density test should be taken and the relative compaction determined for each test section. This was not determined for this study but has been shown to relate to performance in other studies.

13. The most important considerations in establishing future test sections are:

    a. Being sure the bench marks and cross sections are properly established and can be easily located.

    b. That adequate records are kept of traffic, maintenance and similar variables at frequent intervals.

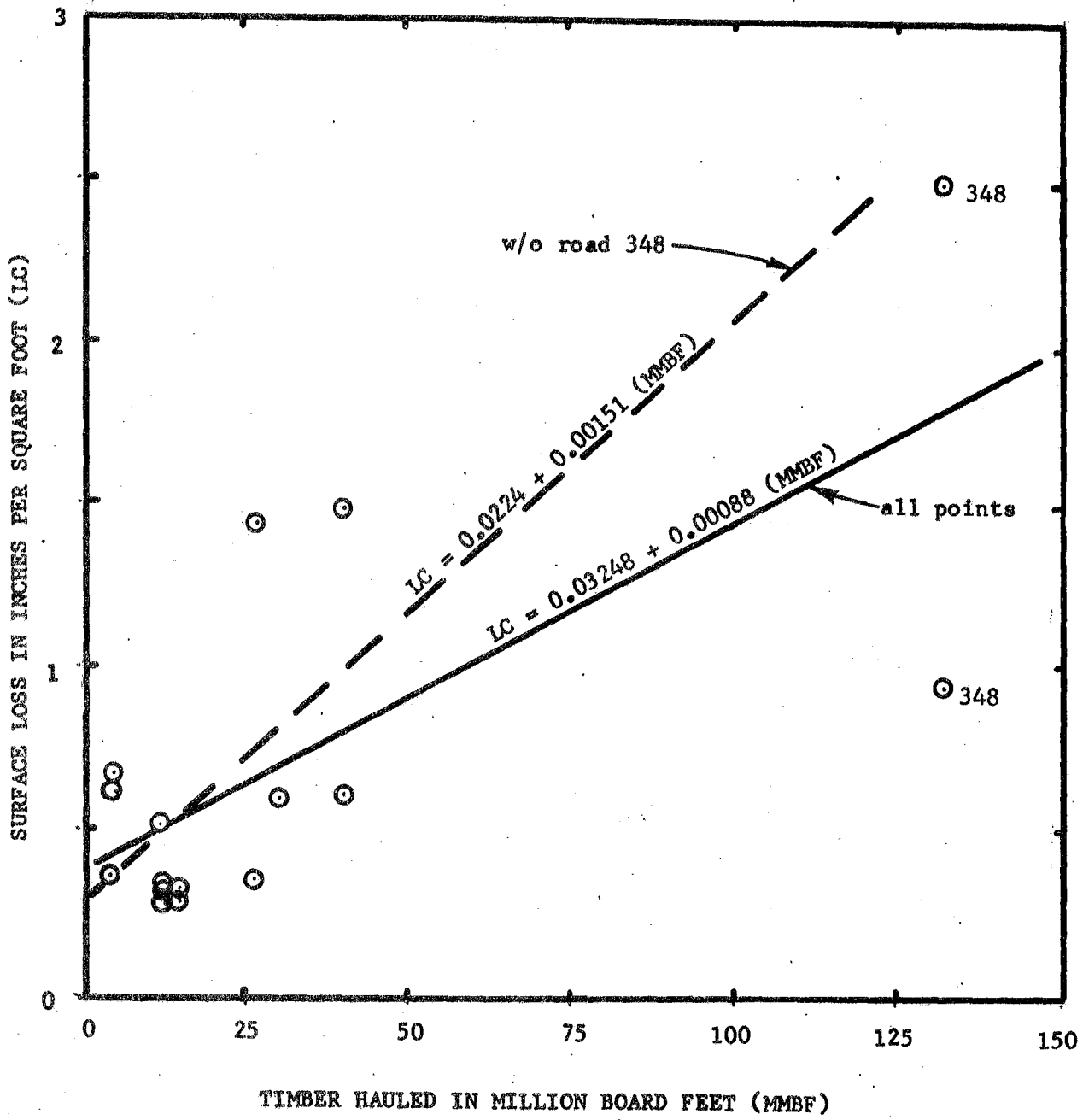

FIGURE 1. Timber hauled vs surfacing loss.
(two year period)

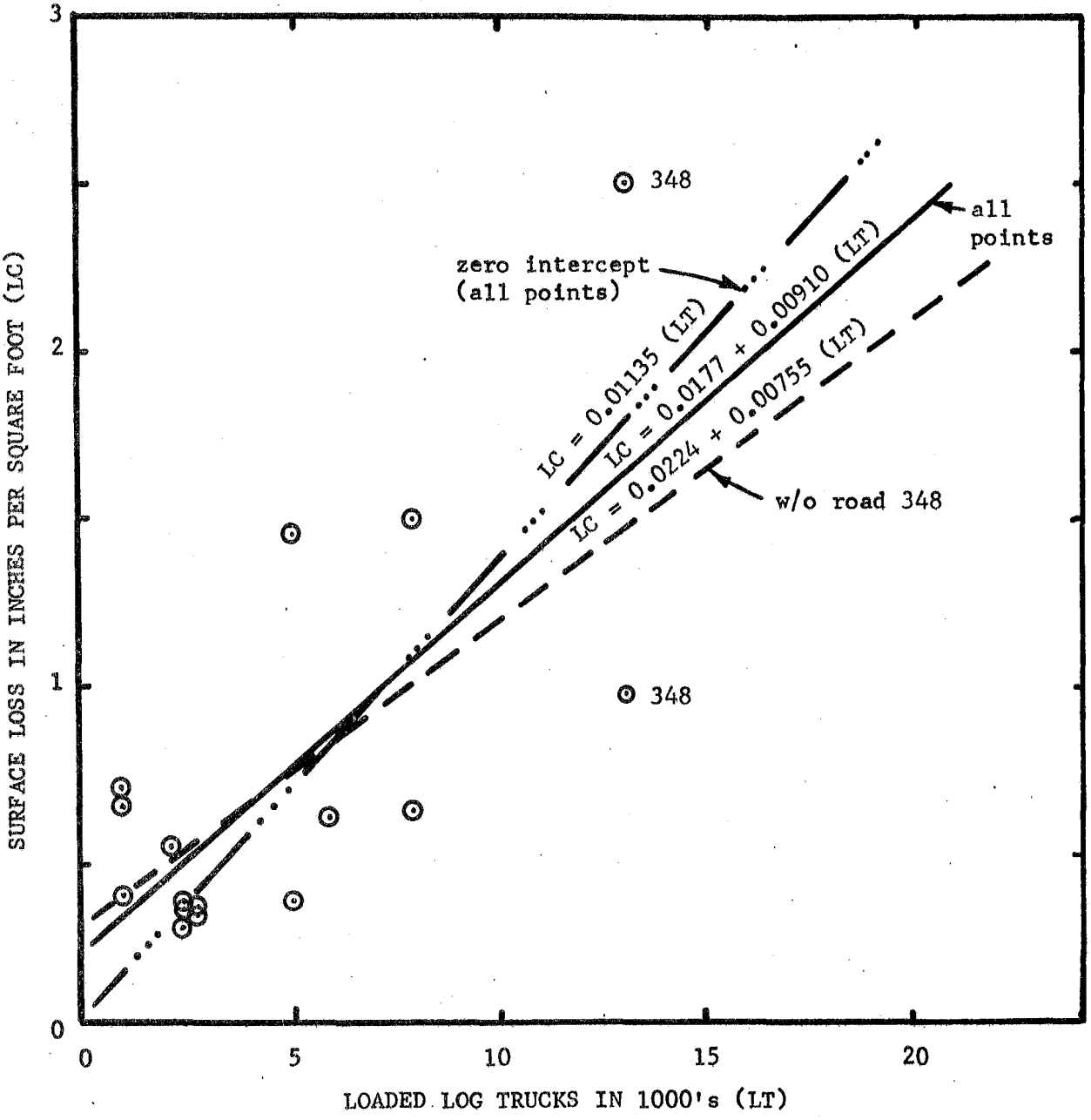

FIGURE 2. Logging traffic vs surfacing loss.
(two year period)

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APPENDIX A

Characteristics of Dependent and Independent Variables

Variable Symbol	Units	Mean	Standard Deviation	Correlation with TLU	TLC	LU	LC
TLU	cy*	5.484	5.804				
TLC	cy*	4.541	4.779				
LU	cu ft/sq ft	.07391	.06634				
LC	cu ft/sq ft	.06141	.04988				
TTU	1000 units	59.91	38.18	.455	.520	.390	.460
MMBF	mill. BF	32.26	40.12	.564	.757	.468	.705
MAINT	# of times	68.56	89.06	.265	.183	.339	.229
SNOW	# of times	13.44	15.76	.290	.249	.370	.297
TS	mph	25.31	9.031	.242	.091	.317	.135
PVS	mph	32.81	8.360	.176	-.001	.219	.029
WIDTH	ft	26.12	5.982	.527	.509	.266	.325
GRADE	percent	4.031	2.941	.500	.642	.443	.633
CURVE	degrees	10.72	20.60	.025	.041	-.012	.012
F/C	-	1.531	.4270	.314	.153	.407	.264
C/G	-	1.625	.5000	-.332	-.131	-.360	-.145
P 3/4	percent	86.44	7.554	-.160	.032	-.246	-.085
P 4	percent	54.25	11.15	.135	.125	.133	.086
P 40	percent	28.75	10.23	.140	.100	.145	.086
P 200	percent	13.46	4.138	-.005	.100	-.098	.036
LL	percent	12.88	13.73	-.003	-.153	.014	-.161
PI	percent	1.500	3.742	-.294	-.256	-.324	-.291
SE	-	40.81	16.69	.198	.121	.165	.071
O-H	inches	2.000	1.735	-.380	-.329	-.400	-.369
O-P20	percent	23.96	6.686	.014	.059	.079	.117
W DEG	-	44.81	22.09	.261	.299	.140	.206
D MAX	pcf	118.1	14.42	-.334	-.236	-.365	-.289
OM	percent	12.68	3.424	.189	.061	.264	.154
ABS	percent	8.788	7.856	.357	.172	.392	.199
SB	-	2.684	.09905	-.343	-.449	-.288	-.431
LAA	percent	28.19	9.108	.410	.269	.469	.328
SSC	percent	8.062	5.211	-.216	-.158	-.188	-.126
SSF	percent	7.956	4.994	-.495	-.421	-.454	-.365
LT	1000 trucks	4.994	3.928	.628	.750	.563	.715
OTU	1000 units	21.40	21.90	-.108	-.170	-.128	-.224

* Cubic yards per test section (75' in length)

Explanation of Variable Symbols

TLU = Loss in cubic yards for the entire 75 foot station, uncorrected for settlement.
TLC = Loss in cubic yards for the entire 75 foot station, corrected for settlement based on the settlement plate.
LU = Loss in cubic feet for one square foot of road surface, uncorrected for settlement (also equals loss in thickness in feet).
LC = Loss in cubic feet for one square foot of road surface, corrected for settlement based on the settlement plate (also equals loss in thickness in feet).

MMBF = Board feet of timber hauled in millions of board feet.
TTU = Total traffic units (two-way) in thousands.
MAINT = Number of times roadway maintained (not the number of passes).
SNOW = Number of times snow plowed from roadway.
TS = Average speed of loaded logging truck in miles per hour.
PVS = Average speed of passenger vehicles in miles per hour.
WIDTH = Average width of cross section in feet.
GRADE = Average grade of station in percent.
CURVE = Horizontal curvature of station in degrees.
F/C = Fill or cut section (fill = 1.0, side cast = 1.5, and cut = 2.0).
C/G = Volcanic cinders or basalt gravel surfacing material (cinders = 1.0 and basalt = 2.0).
P 3/4 = Percent of roadway sample smaller than 3/4 inch in diameter.
P 4 = Percent of roadway sample smaller than the #4 sieve size.
P 40 = Percent of roadway sample smaller than the #40 sieve size.
P 200 = Percent of roadway sample smaller than the #200 sieve size.
LL = Liquid limit of roadway sample.
PI = Plasticity index of roadway sample.
SE = Sand equivalent of roadway sample.
O-H = Height of sediment in inches from Oregon degradation test.
O-P20 = Percent passing the #20 sieve from Oregon degradation test.
W DEG = Washington degradation value for roadway sample.
D MAX = Maximum density in pounds per cubic foot of roadway sample as determined by AASHO T99 test method.
OM = Optimum moisture content in percent corresponding to D MAX.
ABS = Percent moisture absorption as determined in specific gravity test.
SG = Specific gravity of combined aggregate sample.
LAA = Los Angeles abrasion loss in percent.
SSC = Sodium sulfate soundness loss in percent for coarse aggregate.
SSF = Sodium sulfate soundness loss in percent for fine aggregate.

LT = Number of loaded log trucks in thousands.
OTU = Traffic units in thousands for traffic other than logging trucks (mainly passenger vehicles and pickup trucks).

APPENDIX B

PROPOSAL FOR SURFACE LOSS MEASUREMENTS ON SOIL - AGGREGATE ROADS
REVISED AUG. 28, 1970

I. OBJECTIVES

A. To measure all surface wear parameters at widely distributed field stations on many soil-aggregate roads.

B. To utilize the multiple linear regression analysis method for purposes of evaluating the influence of each parameter.

C. To develop an equation for future use in estimating surface loss.

II. SCOPE

A. It is proposed to establish stations and make measurements on approximately ten roads representative of those found in the following four Forests: (1) Winema; (2) Deschutes; (3) Rogue; and (4) Fremont. The individual roads will be selected to include in the total study the following surface types: (1) cinders; (2) crushed gravel; and (3) pit run gravel.

B. The selections will include the various subgrade soils existing in the region.

C. Stations will be selected to include the various influences of traffic, road geometry, and climate. A variety of each will be included in the total of road test sections.

III. METHODS

A. The following variables will be measured:

1. Traffic speed.
2. Volume.
3. Distribution by heavy or light.
4. Timber hauled MMBF.
5. Relative compaction.
6. Properties of gradation, P.I., specific gravity, L.A.R., coefficient of uniformity, coefficient of curvature, S.E., sodium sulphate, and Oregon degradation.
7. Dusting intensity and volume.
8. Geometry of curvature, grade, cuts or fills, and width.
9. Maintenance and snow removal.
10. Age of road.
11. Rainfall.
12. Freeze-thaw cycles.
13. Sunlight and heat.
14. Dust abatement
15. Deflections.

(Some combinations show above. The true total is 29)

B. Establishing Transverse Road Cross Section Stations (4 stations 25 ft. apart for each road section).

1. Bench marks will be established using spikes in the bases of trees, rock outcrops, and steel re-bar as suitable. Two benches will be set to provide for cross checking.

2. Transverse references for line will be constructed of wood hubs or steel re-bar. These will serve as line control and base line points for transverse measurements. These will be taken at one foot increments during testing. The measurements themselves will be taken from a cloth tape. This will not be damaged by any traffic which may pass over it.

3. Plates will be installed to observe any plastic deformation of the subgrade. The individual plate will be of steel, 4"x4"x1/8" set on the subgrade. (Swinton HRB Vol. 18 1938 observed approximately 1/3 of elevation loss in surface was attributed to settlement)

C. Surface Elevations

1. Obtained by differential levels and at one foot increments from the extremities of the aggregate surface.

2. Initial elevations will be read and recorded whenever the station is organized in the summer.

3. Subsequent elevations will be read at the most suitable time elements. Typical elements may be October or November, before any plowing of snow, then late in the spring after thawing and before ditches are "pulled" in maintenance work. Any recording of winter elevations would be invalidated by frost heave.

D. Top of Subgrade Elevations

1. No readings will be made either initially or at any final period of observation. It is assumed that the end area diagrams, created from the initial elevations and any subsequent time interval elevations, will provide a means for calculating volume. Therefore, it will not be necessary to perform the destructive operations of trenching to locate the top of subgrade and to make depth measurements.

E. Dust Measuring Installations

1. Standard collecting buckets will be installed on typical roads. Mr. Wellman will execute this procedure in connection with his Dusting Studies; and his activities may well limit the scope of this phase.

F. Properties of Surfacing Material

1. Samples will be obtained during the time the road section stations are being physically established; and, at the same time, measurements of initial density in place will be made. The field samples will be given all the standard tests for gradation, sodium sulphate, etc.

2. Field samples will again be obtained at the end of any arbitrarily assigned testing period. These will be evaluated to identify the changes which may occur.

3. The specific test values which will be obtained are as follows:

(a) Specific gravity (combined fine and coarse).
(b) Relative compaction of in place density to the AASHO-T99 of the same material.
(c) Sand Equivalent.
(d) L.A.R.
(e) Sodium sulphate.
(f) Oregon degradation.
(g) Gradation.
(h) C_u , coefficient of uniformity.
(i) C_c , coefficient of curvature.
(j) Plasticity

G. Road Geometry

1. Road test sections will be established to include a variety of the following variables:

(a) Widths.
(b) Curvature.
(c) Grade.
(d) Lateral control of surface aggregate by the nature of cut, fill, or berm.

H. Age of Road

1. This will be established from the records.

J. Geography of the Area

1. The latitudes, longitudes, and elevations will be determined for all road test sections.

K. Geology of Surfacing Material Source

1. A geological description will be made for each different source. This will be made at the laboratory, using the samples submitted for other testing and information which can be supplied to the Geologist.

L. Traffic Variables

1. The typical speed will be ascertained from physical observation measurements. The device to be employed is a two station mirror apparatus along with measured distance and time. In detail, the procedure is as follows: (a) one mirror box is placed at each end of a measured distance along the roadside; two boxes are required to permit evaluating traffic from either direction; (b) an observer is stationed exactly midway between the mirror stations; he will be equipped with a stop watch and a tripod supported light meter device; (c) time is measured from initial light signal until registry on the light meter.

2. Volume of traffic will be measured by automatic traffic counters. These will be installed and serviced by the same personnel now assigned to such duties.

3. Traffic distribution will be determined for only two classes, light weight and heavy. If the road test section is on a grade, notation will also be made of whether the heavy weight is loaded uphill or loaded downhill. The method of distributing is as follows: (a) obtain total volume from mechanical counters; (b) obtain data on timber haul from scale tickets; (c) obtain light traffic by difference.

4. Total timber haul variable can be extracted from Item #3.

M. Maintenance Variables

1. Frequency of maintenance will be obtained from Forest Service personnel and from the logging contractors as is possible in any particular road test section case. Frequency will be measured in number of passes with blade.

2. Snow removal occurrences will be determined using the same information sources as #1.

3. Dust abatement activities will be determined as in #1 above. The abatement may be in the form of water, adequate or some degree thereof, oil, or chemical.

4. Dusting intensity will be measured by Mr. Wellman in connection with his studies and correlated to the needs of the Surface Loss Study. In order to be meaningful, the intensity measurements will be made only during the summer months and in the afternoons. The variation from road to road then becomes significant.

5. Dusting volume in average weight per unit area will also be measured by Mr. Wellman according to some as yet undetermined plan.

N. Other Variables

1. Rainfall will be determined from the best possible reporting sources.

2. Road test section exposure to sunlight, the typical temperatures, and humidity will be observed. Unless a constant recording station happens to be nearby, all measurements will be taken in accordance with availability.

3. Freeze-thaw cycles will be determined from whatever local source of intimate knowledge exists in relation to the test section; or, in some cases, a general value for the area may be all that can be obtained.

4. The percent of time the surface is frozen will be determined. The wide geographical scope of this study dictates that these observations, as well as some of the other variables, must be made by local Forestry personnel.

5. Subgrade deflections will be measured with the Benkelman beam wherever possible. Such measurements are most meaningful when observed during the spring thaw period. It is anticipated that Forest personnel in each Forest or a flying team from the Regional Office can obtain these values.

IV. EQUIPMENT AND MATERIALS REQUIRED

A. 1. Settlement plates, steel, 4"x4"x1/8", one installation per test road section, 36 required (approx.)

B. Bench marks, spikes, supplied as required by Forest Service surveying teams from regular source. Small number required per Forest, 10 or 12.

C. Re-bar steel, 1/2 inch diameter by 36 inches long, eight per road test section, total per Forest approximately 50, or total 200 for total Study.

D. Surveying instruments and hand tools supplied by Forest Service teams from regular supplies.

E. Field sampling sacks, 10 per Forest, total approximately 40 sacks.

F. Speed measuring apparatus. Stop watch, light meter device, and mirror signaling apparatus. These are available on a loan basis from OTI.

G. Traffic counters, by Forest Service, require approximately 9 per Forest.

H. Deflection measurements. Required, one Benkelman Beam, not on hand, supply required from Portland Laboratory.

V. SUPPORTING PERSONNEL

Note: The large geographical area involved in the Study indicates the desirability of delegating certain work to the individual Forests and/or Districts therein.

A. Establishing road test sections and their respective stations

1. Regular Forest Service surveying teams (3-man team) in each area.

B. Measuring the Variables

1. Cross section elevations to be obtained by regular surveying teams at time elements previously described under III C.

2. Sampling and field density testing of road surfacing material. To be accomplished by Laboratory personnel of the Forest in which the road exists.

3. Geological descriptions of the sources of surfacing material will be made by the Regional Geologist with the aid of Dr. Lund.

4. Automatic traffic counters to be installed and serviced by Forest personnel who normally perform such work.

5. Freeze-thaw cycles and frequency of snow removal operations will be tallied by local Forest personnel who are most intimately involved in the area work.

6. Benkelman Beam measurements will be taken by a crew of 2 men organized in the most suitable manner for conditions which exist in the spring thaw period of 1971.

VI. WORK PROGRESS

A. August 15, 1970

1. All test sections to be installed.
2. Initial cross section levels completed.
3. Initial surface material samples obtained and forwarded to the Regional Laboratory.
4. All subsequent activities will be measured from this date.

B. Approximately November 1970

1. Measure surface elevations regardless of any maintenance activity.

2. Send initial data to the computer. The entries for quality or characteristics of the rock will be for the conditions existing at the start of the test. The values for traffic volume, rainfall, etc. will be the amounts measured since the start of the test.

C. Depending upon nature of first results and other developments:

1. Re-survey cross sections and calculate surface loss.

2. Sample the surface material and ship. (rock characteristics as submitted to the computer will always be for the conditions at the start of the period)

3. Values for traffic volume, rainfall, etc. will be summarized from the monthly reports filed by the individual Districts.

Submitted By

J. A. Crabtree

J. A. CRABTREE
August 28, 1970

APPENDIX C

Computer Run Stream Using BMD 02R*
Includes listing of original data.

* For format information refer to:

"BMD - Biomedical Computer Programs," W. J. Dixon, Editor, University of California Press, Berkley and Los Angeles, 1968, pp. 233-257.

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4000 PROBLM   SLOSS    16   32                    1  32                    1
5010 LABELS   1TLU      2TLC      3LU       4LC       5TU       6MMBF     7MAINT
5020 LABELS   8SNOW     9TS      10PVS     11WIDTH   12GRADE   13CURVE   14FIC
5030 LABELS  15C1G     16P314    17P 4     18P 40    19P 200   20 LL     21 PI
5040 LABELS  22 SE     23 G-M    24.0 P20  25W DEG   26D MAX   27 UM     28 ABS
5050 LABELS  29 SG     30 LAA    31 SSC    32 SSF
5060 (8X,9F8.0/2X,F6.0,9F8.0/2X,F6.0,9F8.0/8X,3F8.0)
5070 103513-30001.3260001.326000.0570000.057000014.5000005.100000014.0000000.00000020
5080 1000003000024.5000003.0000009.0000002.0000002.00000081.0000044.0000024.000014.9
5090 1000000000000000000028.000001.9000027.60000041.000103.0000018.7000004.800002.64
5100 0000001000025.000010.1000016.5
5110 200286-10007.1700005.038000.0710000.051000134.9300029.620000279.0000041.00000025
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5130 2000002200000000000075.000000.5000027.70000068.000107.8000015.2000015.900002.69
5140 0000002000039.000003.9000003.2
5150 300286-20009.6010005.824000.2048000.124800096.7900039.580000227.0000045.00000040
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5240 5000005000028.0000001.5000000.0000001.0000001.00000096.0000067.0000031.000014.5
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**********END OF FILE

Surface Loss Study - Roads Employed

No.	Forest	Number	Name	District	Material
1	Winema	35013	Copperfield	Chiloquin	Pit Run Gr.
2	Winema	286	Bear Flat	Chemult	Cinders
3	Winema	33061	East-West	Chiloquin	Cinders
4	Fremont	2800	Buck Creek	Silver Lake	Cinders
5	Fremont	348	Chewaucan	Paisley	Pit Run Gr.
6	Rogue	3900 & 3900-C	Carberry Creek	Applegate	Cr. Rock
7	Rogue	County	South Fork Little Butte	Ashland	Cr. Rock
8	Rogue	3017	Abbott Creek	Prospect	Cr. Rock

Each road has three test sections 75 feet long except for road No. 348 which has only two sections. (Total = 23 sections.) The sections were selected to provide a variety of curvature, grade, width, speed, ditching, fills, and cuts.